Submarine-Based Acoustic Doppler Current Profiler (ADCP) Measurements of the Upper Arctic Ocean

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LONG-TERM GOALS

Long-term goals of this project are to better understand and quantify the processes that are primarily responsible for redistribution of heat and salt within the Arctic Ocean. The topical focus has been on quantification of the slope-trapped boundary currents and on understanding the roles of small-scale and mesoscale processes in the redistribution of water properties within the central basins. The geographical focus spans the Arctic Basin but emphasizes the Nansen, Amundsen and Makarov basins and the frontal systems that overlie the inter-basin ridges.

OBJECTIVES

Four primary objectives contribute to the above goals.

- Improve the present understanding of mean circulation patterns in the Arctic, with a focus on the topographically controlled boundary currents that redistribute heat and salt.
- Quantify the speeds, heat, salt and mass transports associated with the boundary currents.
- Improve our understanding of the nature, distribution and dynamics of upper ocean mesoscale eddies and frontal systems, and assess their role in the transport of heat and salt.
- Assess the roles of turbulent mixing and double diffusion in redistributing heat and salt, with an emphasis on the impact of these processes on the halocline.

APPROACH

We approach the above goals through analyses of recently collected field data. The core dataset has been collected from submarine deployments in 1995, 1996, 1997, 1998 and 1999. These data span the entire Arctic Ocean and include temperature (*T*), salinity(*S*), dissolved oxygen (*DO*) and upper ocean currents. These data are supplemented with *T*, *S* and current data collected during 1993, 1995 and 1996 cruises of the German research icebreaker *Polarstern*, with data from the 1994 US/Canadian trans-Arctic section, and time series data from an array of instrumented moorings that were deployed off the Siberian continental slope from 1995-1996. Data analysis methods include water mass and time series analyses and intercomparisons among the data and a broad variety of analytical and numerical model results. At present we are focussing on a small number of specific process-related problems while at the same time working toward an integration of the several datasets that should help

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to provide a holistic view of the Arctic Ocean, its primary circulation and significant internal processes.

WORK COMPLETED

Results from this project were presented at the meeting of the Polar Research Board in Washington, DC during October, 1999. The presentations included lessons learned from the SCICEX program, and the SCICEX results contributed to discussions concerning a dedicated nuclear submarine for civilian research.

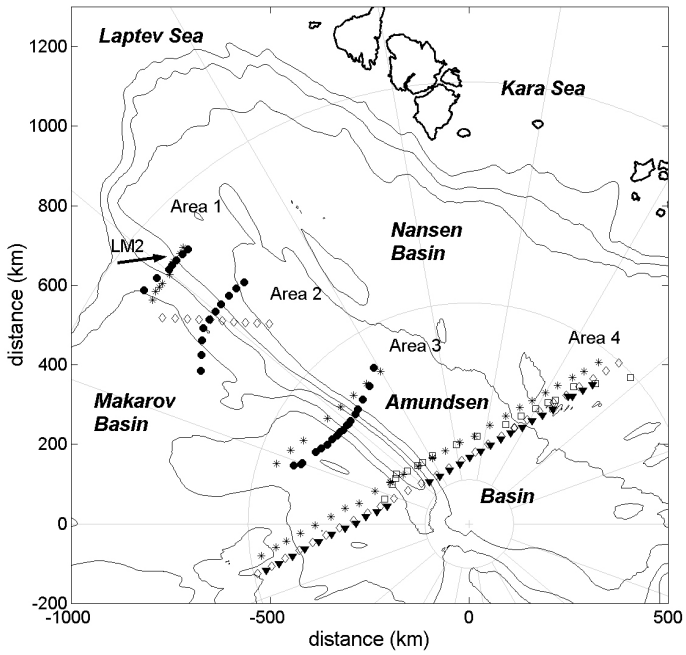
Results were presented at the Arctic System Science Ocean-Atmosphere-Ice Interactions workshop in Virginia Beach, Virginia, also during October 1999. Results included findings from the SCICEX 1998 cruise relating to the study of the frontal zone over the northernmost portion of the Arctic Mid-Ocean Ridge [*Muench and Gunn*, 1999]. Presentations on ocean transport pathways of Eurasian Arctic river discharge [*Guay et al*, 1999] and variations of the Barents Sea outflow as deduced from moored observations at the junction of the Lomonosov Ridge and the Eurasian continent [*Woodgate et al*, 1999] were presented jointly with investigators from other programs.

Analyses have been presented of the combined data from the SCICEX program and other Arctic Ocean surveys from the decade of the 90's at the European Geophysical Society meeting in Nice, France in April, 2000 [*Muench and Gunn*, 2000]. These analyses dealt with the warming of the temperature maximum in the Atlantic Water during the decade and the subsequent stabilization of this warming trend in the latter part of the decade. These results have been submitted as an article to *Geophysical Research Letters* [*Gunn and Muench*, 2000].

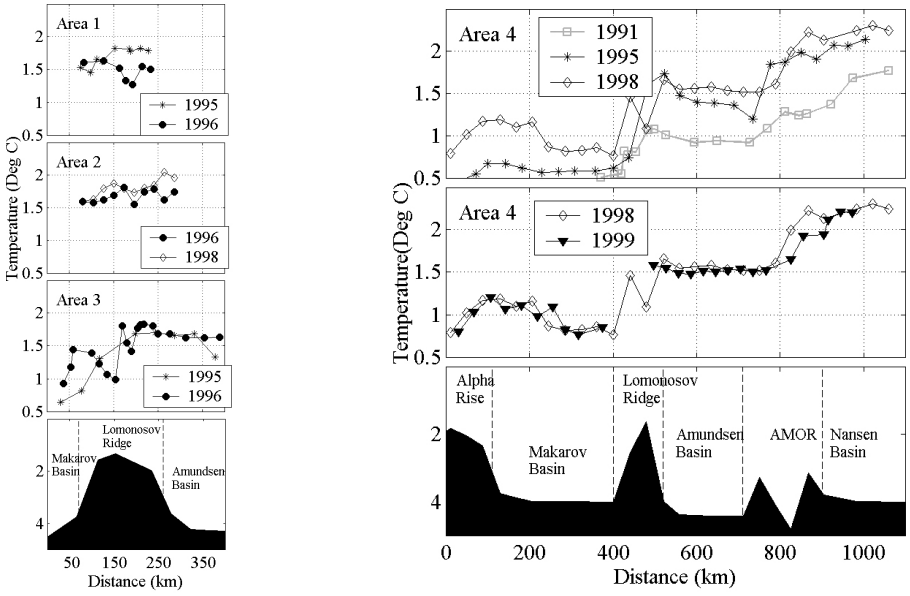
The analysis of a cold core eddy observed during the 1997 SCICEX program was completed and resulted in a article accepted in the *Journal of Geophysical Research* [*Muench, et al*, 2000].

RESULTS

We have used a compilation of multiple T and S profile surveys in the Arctic Ocean over the past decade to evaluate changes in the upper portion of the water column in the Arctic Ocean. Ocean temperature data obtained from the central Arctic Ocean during 1995-1999 show interannual changes in the temperature maximum (T_{max}) of the warm Atlantic Water core. Widespread warming, which had begun by early in the decade, continued from 1995 until 1998 but had ceased during 1998-1999 and was replaced by a slight cooling. The timing of these changes differed regionally, as the warming had occurred prior to 1995 in the Nansen and Amundsen basins, and between 1995 to 1998 in the Makarov Basin. The regional phase differences are consistent with advection along mid-ocean ridges from the Eurasian margin slope current, which provides the source for warm Atlantic Water. Anomalous behaviors were associated with the Arctic Mid-Ocean and Lomonosov ridges and probably reflected the presence of overlying topographically trapped circulations.



Geographical distribution of vertical *T* profiles obtained along four sets of transects, defined here as falling in Areas 1-4, that are used to assess Atlantic Water T_{max} changes. Years when the transects were occupied are indicated on figures below. Isobaths derived from the ETOPO-5 database are shown at 1000 m intervals. LM2 is the location of year-long (1995-96) moored instrumentation.



Atlantic Water maximum temperature, T_{max}, plotted versus distance along transects, for each year when data were acquired, within each of Areas 1-4 as defined on upper figure. The bottom depth profile is a composite constructed using the 1995, 1998 and 1999 sounding data. Temperature fronts that overlie the Alpha Rise, the Lomonosov Ridge and the AMOR are evident.

IMPACT/APPLICATIONS

The results concerning Arctic Ocean warming have implications, which we are even now trying to understand and quantify in this program, with respect to the diminishing Arctic Ocean pack ice cover. Changes in the ice cover, and related changes in the upper ocean structure, have a potential impact on Naval operations and upon strategic interest as well as interacting with globally changing climate.

TRANSITIONS

Results from this program are of critical interest within the context of planning for the international SEARCH Program, which seeks to evaluate Arctic climate change. The SEARCH Program is being planned by a number of foreign and US governmental research agencies.

RELATED PROJECTS

Results on upper ocean mixing processes are being directly integrated with results being obtained from the Weddell Sea AnzFlux (Antarctic Zone Fluxes) and international DOVETAIL (Deep Ocean Ventilation Through Antarctic Intermediate Layers) programs. The integrated results will provide information on the relationships among wind-driven surface currents, tidal currents, sea ice cover, upper ocean stratification and mixing processes over a spectrum of parameter values that typify high latitude oceans.

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